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Automatic registration feasibility study: The use of sampling techniques for vertical registration error detection

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AUTOMATIC REGISTRATION FEASIBILITY STUDY: THE USE OF SAMPLING TECHNIQUES FOR VERTICAL REGISTRATION ERROR DETECTION

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AUTOMATIC REGISTRATION FEASIBILITY STUDY: THE USE OF SAMPLING TECHNIQUES FOR VERTICAL REGISTRATION ERROR DETECTION

SUMMARY

A colour camera registration error detector has been described[1] *whose output indicates the horizontal offset of one scanned image with respect to another. The equipment to be described is based on the same basic principles but, by using electronic sampling techniques, indicates the vertical offset of one image with respect to another. The detector operates satisfactorily from normal picture information and does not require the use of a special test-chart.*

1. INTRODUCTION

A colour television camera is correctly registered when the signals from each camera tube relating to any point in the scene are coincident in time. In a system of registration error detection, one of the camera tubes is selected as a reference or 'master' tube, and the remainder are designated as 'slave' tubes. The detection system determines the direction of the displacement of a slave-tube image with respect to the master-tube image. The magnitude of the error is not precisely measured since only an indication of an error is required to enable correction to be applied.

This report is concerned with the instrumentation of an error detector operating in the vertical (field) direction, with particular reference to the sampling techniques employed. These techniques are illustrated by their application to a detector based on the principles described in an earlier Report[1], which are summarized below.

2. PRINCIPLES OF OPERATION

The coincidence in time of transitions, representing picture detail, in the output signals from two camera tubes forms the basis of the detection technique. In the case of a detector operating in the horizontal (line) direction, the picture detail is selected by differentiating each tube output signal. The degree of coincidence is measured by subtracting the differentiated slave-tube output from the differentiated master-tube output and full-wave rectifying the difference. The result is a minimum at the point of maximum coincidence of detail, i.e. at the point of best registration. Subsequent integration provides a detector output proportional to the algebraic average of registration errors; the output of the detector may correspond to only a pre-determined section of the picture if suitable gating arrangements are used.

In order to resolve registration errors in the field-direction, a system of vertical scanning must be simulated which will generate the required field-waveforms. A field-waveform is produced from each camera-tube output and is subjected to the same system of signal processing as that outlined above for the detection of horizontal registration errors. However, the derivative of a field-waveform corresponds to the horizontal edges in a picture and thus the detector gives an indication of any vertical offset between images from the master tube and slave tube.

3. THE USE OF SAMPLING TECHNIQUES

Sampling techniques are used to produce the field-waveforms (i.e. similar to those waveforms which would be obtained by vertical scanning at the original field rate), and to provide the delays necessary to obtain the derivatives of the field waveforms. These delays could be provided by conventional means of delaying television signals, but would be expensive and bulky.

3.1. Generation of a Field-Waveform

The line-period is sub-divided into a number of equal time intervals. During each field a corresponding interval on every line is selected for sampling purposes, the interval selected commencing after a given delay with respect to the start of each line-period. These time intervals are defined by the output from a gating-pulse generator which, when displayed on a television monitor, appears as a vertical stripe on the picture. The duration of the sampling interval (or width of the displayed vertical stripe) is determined by the degree of line-period sub-division necessary for the effective functioning of the detector; in the prototype detector the duration of the sampling interval is 4·5 μs. The signal obtained by sampling during each interval is integrated and the result of the integration is stored on a capacitor for one line-period, i.e. until the time when the sampling and integration of information from the next line of the field takes place. The resulting field-waveform generated by such a sample-and-hold circuit consists of a series of amplitude-modulated pulses, each with a duration equal to one line-period. In order to improve the representation of the picture signal that would have been obtained had vertical scanning been used, some form of interpolation between the amplitude-modulated field pulses would be required.

An electronic grille, as shown in Fig. 1(*a*), provides a relatively simple field-waveform which will be used to explain the operation of the vertical error detector; Fig. 1(*a*) includes an outline of the vertical stripe defining the line sampling intervals for a given field. The integral of the line information during a sampling interval will be a maximum when the line selected coincides with a white video signal corresponding to one of the horizontal lines in the grille; this field-waveform is shown in Fig. 1(*b*), (the time interval between the maxima has been compressed for convenience). A more realistic field-waveform is shown in Fig. 1(*c*) where a linear interpolation between the field samples has been performed. The relative merits of these two forms of field-waveform will be discussed later.

The vertical stripe produced by the gating-pulse generator during one field represents only one scan of the simulated vertical scanning system, and if its position during the line-period were fixed it would only provide the detector with information from a small fraction of the total picture area. This detector is, however, required to operate from normal television picture information and consequently, if the field-waveform were generated from only a small fraction of this picture area, and this fraction happened to contain much fine colour detail, this detail could be interpreted as a misregistration and spurious detector-outputs would be generated. Further, by limiting the effective picture area, the chances of locating suitable field information for misregistration detection would be reduced, and the sensitivity of the detector impaired. It is important therefore, that the simulation of a vertical scanning system should be substantially complete. In order to do this, the sampling intervals selected on each line are moved, in the line-direction, to their next adjacent position (defined by the line-period sub-division) for each successive television field.

3.2. The Provision of One-Line Delays

A series of one-line delays is necessary in order to produce the required derivatives of the field waveforms and to provide the linear interpolation shown in Fig. 1(*c*), if such interpolation is required.

The delays are introduced by re-sampling the amplitude-modulated pulses constituting the field waveform after it has been passed through a network with a delay equal to a small fraction of one line-period (see Figs. 2(*a*) and 2(*b*)). The delay may be a simple low-pass filter and the re-sampling pulses, derived from the gating-pulse generator, are repeated at line-frequency. The timing of these pulses with respect to the field-waveform after it leaves the short delay is illustrated in Fig. 2(*c*). The re-sampled waveform is again stored for one line-period in a capacitor, and Fig. 2(*d*) shows that the field-waveform has been effectively delayed by one line-period. An accumulative delay equal to a multiple of one line-period can be obtained by passing the field-waveform through a series of the short-delay and sample-and-hold circuits.

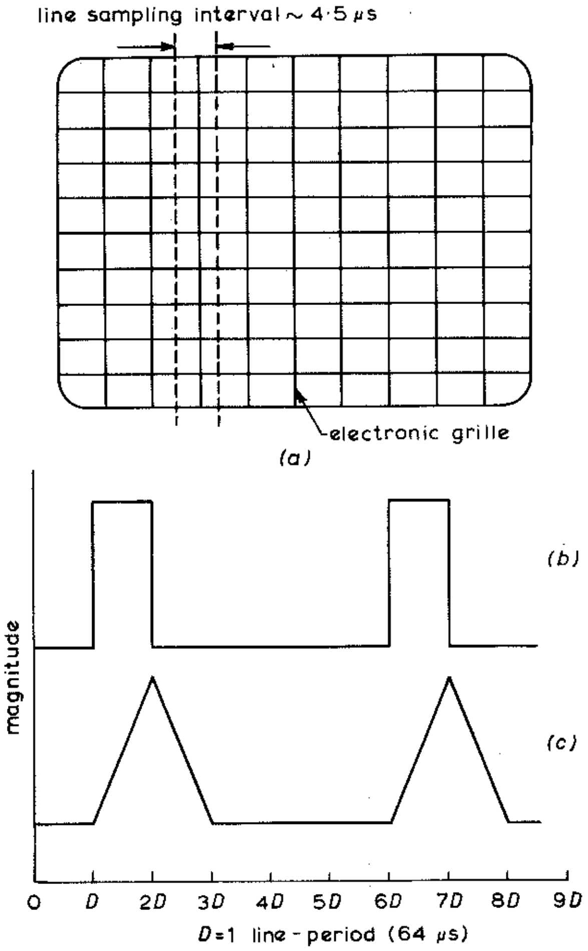

Fig. 1 - Field-waveforms produced by electronic grille

(*a*) A position of the line-sampling interval corresponding to a single vertical scan
(*b*) Field-waveform without interpolation
(*c*) Field-waveform with linear interpolation

4. THE EMBODIMENT OF SAMPLING TECHNIQUES INTO A COMPLETE VERTICAL ERROR DETECTOR

A characteristic of the vertical-error detector which must be considered is the maximum registration error which it is capable of resolving. This

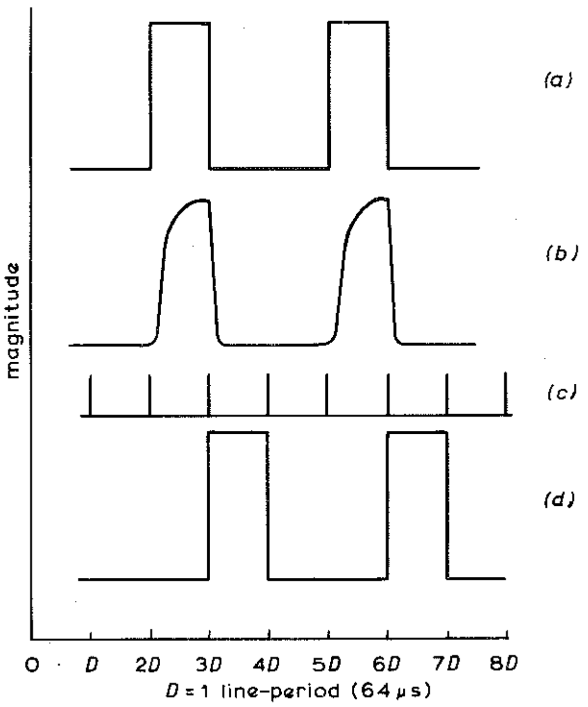

Fig. 2 - Generation of one-line delay in the field-waveform

(*a*) Input field-waveform
(*b*) Output from delay network
(*c*) Re-sampling pulses
(*d*) Field-waveform delayed by one-line period after re-sample/hold

range of operation can be extended by increasing the distribution in time of information carried by the derivatives of the field-waveforms. The spread of information is greater for field-waveforms with interpolation (Fig. 1(*c*)) than it is for waveforms without interpolation (Fig. 1(*b*)). Both types of waveform were used with the prototype detector and it was ascertained that, even without interpolation, the operating range of the detector was quite sufficient to match the performance of the error detector working in the line direction. The instrumentation of the detector was therefore simplified.

The following description is concerned with the prototype vertical error detector. It is sufficient to describe error detection between the master tube and one slave tube; the detector was designed to provide an operating range equal to the maximum for field-waveforms without interpolation.

4.1. Error Detection

A single registration response for a master channel output (A) and a slave channel output (B) is shown in Fig. 3(*a*), the integrated output from the full-wave rectifier being a minimum at the point of correct registration. In order to sense the direction of the registration error, two responses are generated as shown in Fig. 3(*b*), offset to either side of the original response by delaying the signals A and B respectively.[1] The difference between these responses is amplified to provide the detector output. On either side of the point of correct registration the polarity of the difference between the two offset responses is interchanged and hence the polarity of the output from the amplifier changes and provides information concerning the direction of the error.

To extract detail from a field-waveform, $A(t)$, $B(t)$ etc. the derivative is generated as

$$\frac{\Delta A(t)}{\Delta t},$$

etc. where Δt is equal to one line-period. The subscripts to A and B shown as A_D, B_{2D} ... etc. indicate the delay suffered by the respective field-waveforms, in multiples of the line-period (D). In the discussion below, the following equality is observed:

$$\frac{\Delta A(t)}{\Delta t} - \frac{\Delta B(t)}{\Delta t} = \frac{\Delta\{A(t)-B(t)\}}{\Delta t} \qquad (1)$$

It will be shown later that, with a field-waveform which has not been interpolated, a two-line offset in the registration responses provides the detector with its maximum operating range. The two difference signals are therefore $(A-B_{2D})$ and $(A_{2D}-B)$.[1]

The derivatives of the above difference signals are:

$$(A-B_{2D}) - (A-B_{2D})_D \qquad (2)$$

and

$$(A_{2D}-B) - (A_{2D}-B)_D \qquad (3)$$

These expressions may be rewritten:

$$(A+B_{3D}) - (A_D+B_{2D}) \qquad (4)$$

and

$$(A_{2D}+B_D) - (B+A_{3D}) \qquad (5)$$

Equations (4) and (5) therefore represent the signal inputs to the two full-wave rectifiers. The block

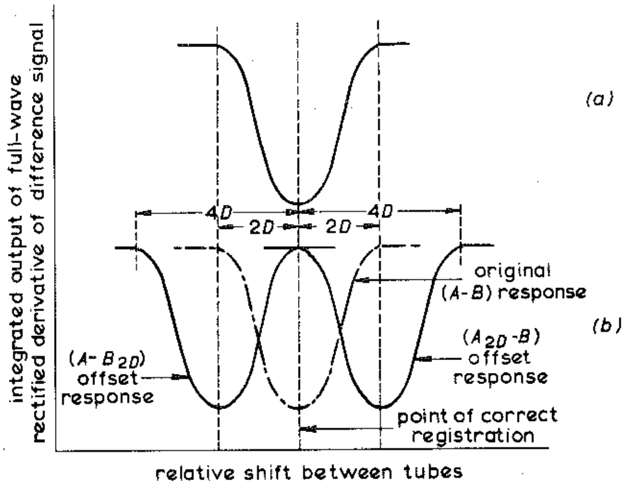

Fig. 3 - Registration responses for the prototype detector

(*a*) Original (A–B) response
(*b*) Offset responses

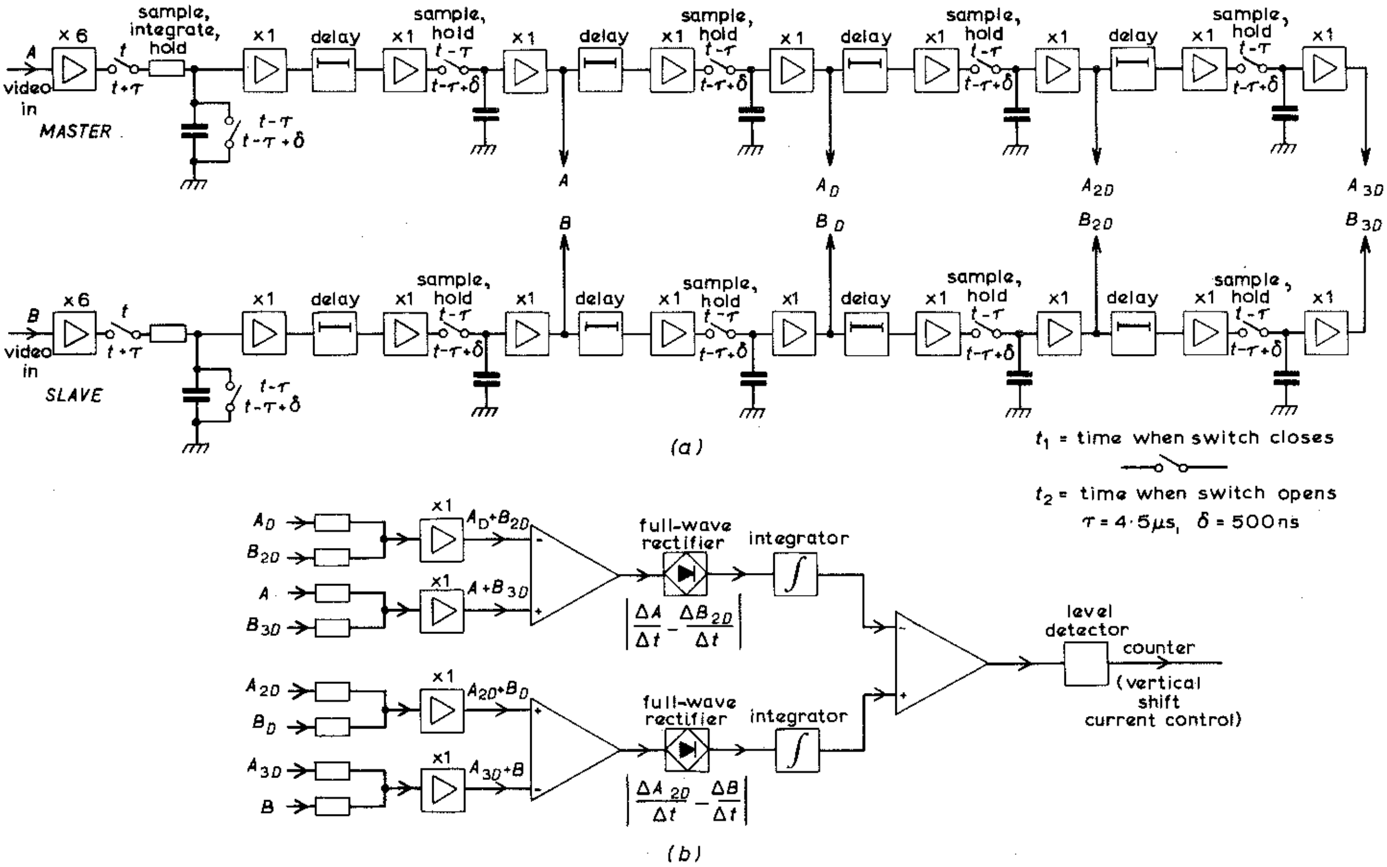

Fig. 4 - A vertical error detector operating between the master tube and one slave tube

(*a*) Generation of multiple line-delays in the field-waveforms
(*b*) Processing of field-waveforms required to provide the detector output

diagrams of Fig. 4 illustrate how these signal inputs are derived and incorporated into a vertical-error detector operating between a master tube and one slave tube.

A level detector is used to sense the polarity of the output signal and subsequently controls the vertical shift current in the yoke of the slave tube concerned in order to achieve a condition of correct vertical registration.

With the camera viewing a grille pattern and vertical detail being taken from the whole of the picture area, the sensitivity of the prototype detector is 220 mV per equivalent nanosecond[*] of vertical registration error. The thresholds used by the level detector enable correct registration to be maintained to within ± 5 ns.

4.2. Operating Range of the Vertical Error Detector

In order to understand the dependence of the operating range upon the nature of the field-waveform derivatives, it will be assumed that electronic-grille video waveform is used as the inputs (A and B) of the detector, *i.e. a condition of perfect registration is represented.* This approach helps in the comparison between different versions of a field-waveform.

4.2.1. Operating Range without Interpolation

The derivative of a field-waveform without interpolation is illustrated in Fig. 5(*a*). The input to each full-wave rectifier consists of the difference between two derivatives, one from the master tube and one from the slave tube, separated in time by two line-periods. The two derivatives and the output from the full-wave rectifier are shown in Fig. 5(*b*) and Fig. 5(*c*) respectively; it is the integrated output from each rectifier which generates one of the offset registration responses illustrated in Fig. 3(*b*). If the separation between the two derivatives shown in Fig. 5(*b*) is increased, the mean level of the rectified output does not change. However, if the separation is decreased the derivatives begin to overlap and the mean level of the rectifier output will change and continue to change provided that information from the two derivatives is superimposed i.e. for a total displacement of four line-periods in each response. Consequently the point of correct registration must be located with respect to the two offset registration responses as shown in Fig. 3(*b*). If an attempt is made to increase the range of the detector by increasing the offset beyond two line-periods, the cross-over point of the two registration responses in Fig. 3(*b*) is no longer well defined and therefore gives rise to an indeterminate point of correct registration. The offset of two line-periods therefore provides this version of the detector with its maximum operating range.

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[*] Horizontal registration errors are expressed as the timing error in nanoseconds between any two images when scanned at the 625-line, 50 fields per second rate. Vertical registration errors are also expressed in nanoseconds assuming that the two images had been scanned vertically at the horizontal scanning velocity.

The responses of Fig. 3(*b*) indicate that vertical registration errors are capable of being detected within a range of ± 4 lines from the reference provided by the master-tube. However, because the detector is working with an interlaced television scanning system, the effective range is ± 8 picture lines as far as the actual display is concerned.

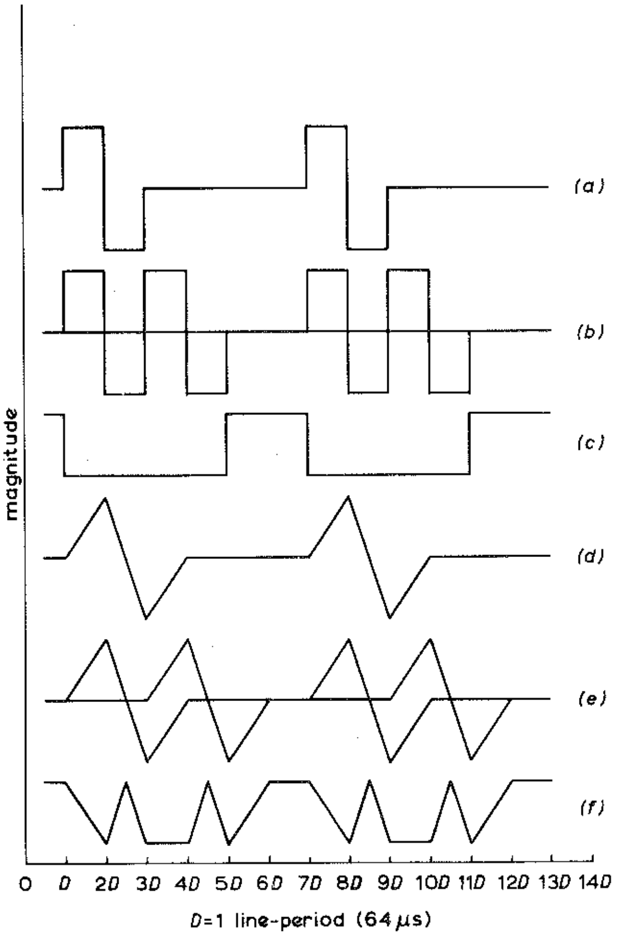

Fig. 5 - Output from full-wave rectifier under conditions of perfect registration

(*a*) Differentiated field-waveform without interpolation
(*b*) Input differentials with a two-line offset between master and slave channels
(*c*) Rectifier output without interpolation
(*d*) Differentiated field-waveform with linear interpolation
(*e*) Interpolated input differentials with a two-line offset between master and slave channels
(*f*) Rectifier output with linear interpolation

4.2.2. Operating Range with Linear Interpolation

The derivative obtained from a linearly interpolated field-waveform is shown in Fig. 5(*d*). Information from this derivative is now distributed over three line-periods and the rectifier output derived from two input derivatives separated by two line-periods is shown in Fig. 5(*f*). A comparison between Fig. 5(*b*) and Fig. 5(*e*) shows that, even at the point of correct registration, information from these two derivatives is superimposed. It is this factor which gives this version of the vertical error detector a potentially larger operating range than its counterpart. If the separation between the derivatives of Fig. 5(*e*) is increased, the mean level of the rectifier output continues to change for one line-period and then remains constant. The relationship of the point of correct registration to the responses offset by two line-periods is shown in Fig. 6. The cross-over point of the two responses is now well defined and the offset of each response could be increased to three line-periods before giving rise to an indeterminate point of correct registration.

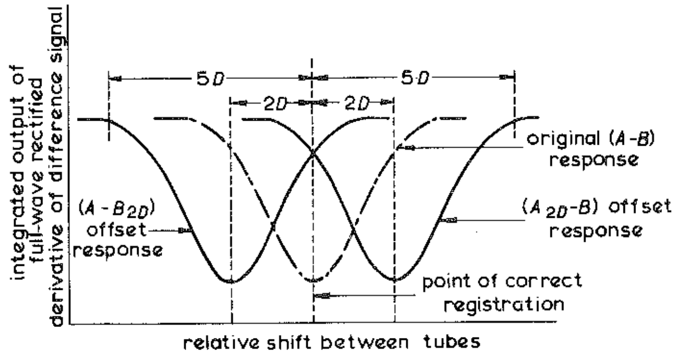
integrated output of full-wave rectified derivative of difference signal
5D
5D
2D
2D
original (A-B) response
(A - B2D) offset response
(A2D-B) offset response
point of correct registration
relative shift between tubes

Fig. 6 - Registration responses with a linearly-interpolated field-waveform

The maximum range of this detector is therefore ± 6 lines from the reference provided by the master-tube, being equivalent to ±12 picture lines on an interlaced television display.

4.3. Optimization of the Sampling Interval

A complete registration system will have a horizontal-error detector and a vertical-error detector working simultaneously from the same picture information. If a picture contains a large number of diagonal edges the contributions to a registration error by vertical and horizontal offsets may be misinterpreted by the two detectors. The sensitivity of the vertical-error detector will depend upon the number and magnitude of transitions in the field-waveforms. By increasing the duration of the line-sampling intervals the field transitions may be selectively enhanced for truly horizontal edges in the picture. The horizontal edges give a direct indication of the existence of a vertical registration error between the master tube and a slave tube. Consequently, by increasing the sampling interval, it is possible to minimize the 'cross-talk' between horizontal and vertical detectors. However, the efficacy of this improvement is dependent upon picture information. It is required that the detector should operate from normal studio scenes and the presence of a suitable amount of horizontal picture detail cannot be guaranteed. In these cases, an increase in the sampling interval reduces the overall sensitivity of the detector and measurements indicate that this reduction in sensitivity offsets to a large extent the improved 'cross-talk' protection. Consequently, it is only the required sensitivity of the detector which determines the duration of the sampling interval.

The sensitivity investigations were carried out on picture information obtained from a representative studio scene and were measured in terms of the vertical shift required in the slave channel to produce a change in the output from the detector of 1 volt. This shift corresponds to the error that would exist at the detection thresholds if these were set at ± 1 volt and therefore gives an indication of the error likely to remain uncorrected.

The result of the measurements suggest that a sampling interval less than or equal to $4{\cdot}5\,\mu$s should be used for the vertical error detector (a sharp decrease in sensitivity was observed for sample widths of $8\,\mu$s).

5. CONCLUSIONS

It has been established that satisfactory operation of a vertical error detector may be obtained by ensuring that the two offset registration responses have a well-defined cross-over point. The greater the slope of the responses at the cross-over point the greater will be the sensitivity of the detector to vertical registration errors.

An example has been given of the prototype detector operating at its maximum useful range. If each response offset were reduced to one line-period the sensitivity of the detector would increase due to an improvement in the cross-over point, although its effective range would decrease.

Linear interpolation between the field samples increases the operating range of the detector although the balance between sensitivity and range is still controlled by the offset of the two registration responses. (The generation of linear interpolation requires the provision of integrating circuits and extra one-line delays.) The design of the final detector requires an optimization between the parameters of sensitivity, range and circuit complexity.

The output from the vertical-error detector may be used to control the vertical shift of an image from a slave-tube with respect to that from the master-tube. It is important therefore, that information obtained from the field-waveforms should represent an error which can be corrected by a 'shift-only' control. The sampling of information should therefore be inhibited at the edges of a picture where geometrical errors could predominate.

The use of the sampling techniques described, particularly for the generation of one-line delays, has enabled a compact and versatile vertical error detector to be developed which has proved to be effective in supplying the information required for vertical registration-error correction.

6. REFERENCES

1. Automatic registration feasibility study: a simple registration error detector. BBC Research Department Report No. 1969/50.

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